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Effects of heat on workers' health and productivity in Taiwan

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***Background*:** The impact of global warming on population health is a growing concern and has been widely discussed. The issue of heat stress disorders and consequent productivity reduction among workers has not yet been widely addressed. Taiwan is an island straddling the Tropic of Cancer in the West Pacific and has both subtropical and tropical climates. As of 2008, the economy of Taiwan accounts for 1.1% of the world gross domestic product at purchasing power parity and is listed as 19th in the world and eighth in Asia, according to International Monetary Fund data.

***Objective*:** The aim of this paper is to identify occupations at risk and the potential health impacts of heat on workers in Taiwan.

***Design*:** Historical data relating to meteorology, population, the labour force and economy were obtained from publicly available databases from the Taiwanese government.

***Results*:** Hot seasons with an average maximum temperature above 30°C and relative humidity above 74%, lasting for four to six months from May to October, pose health threats to construction, farming and fishery workers. In particular, populations of ageing farmers and physically overloaded construction workers are the two most vulnerable worker categories in which high temperature impacts on health and productivity.

***Conclusions*:** Currently, regulations and preventive actions for heat relief are difficult to enforce for several reasons, including lack of equipment for measuring environmental conditions, lack of awareness of potential hazards and strict time constraints imposed on workers. There is an urgent need to systematically and comprehensively assess the impact of a warming climate on workers' health and productivity to provide effective prevention strategies for a better working and living environment in Taiwan.

Keywords: *occupational health*; *global warming*; *hot temperature*; *heat stress disorders*; *productivity*

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In 2007, three consecutive days of high temperatures, from 33 to 34°C, at the end of May resulted in the deaths of three 80-year-old farm workers in a rural area in southern Taiwan while they were working outdoors (1). In July 2009, a 40-year-old live-line worker died of heatstroke. He had begun work at noon, conducting electrical equipment maintenance, wearing protective clothing and a helmet at a temperature of 33–34°C (2). Such incidents highlight how excessive heat exposure can cause death during hot summer seasons in Taiwan. During 2006–2007, a total of 22 deaths were officially attributed to excessive heat (E900 as classified by ICD-9) by the Department of Health in Taiwan (3). However, the exact issue of how the climate affects population health and productivity is still unclear because there has been no nationwide study or surveillance of this issue.

Taiwan's geography and climate

Taiwan, with a population of 23 million, is an island located between 21.5–25.2°N and 120–122°E. This island straddles the Tropic of Cancer in the western Pacific, with both subtropical and tropical climates. The climate of Taiwan is characterised by relatively high year-round temperatures and humidity, usually accompanied by heavy rain and tropical cyclones during the summer.

Taipei (25.5°N) and Kaohsiung (22.4°N) are the two largest municipalities in Taiwan and are located to the north and south of the Tropic of Cancer, respectively. These two areas have the largest populations and the most ongoing construction projects in Taiwan, such as new high-rise apartments, commercial centres and underground transportation systems. Their respective population sizes are 6.5 million in Taipei and 2.8 million in

Kaohsiung (4). The major economic activities of these two areas are commercial and light manufacturing industries, for instance the information technology industry (Standard Industrial Classification (SIC) codes 357, 365–367, 369, 481–484 and 489) in Taipei and heavy manufacturing industries, such as the petrochemical industry (SIC code 29), in Kaohsiung. Taichung (24.9°N), with a population of 2.6 million, is the third largest metropolitan area in Taiwan. Taichung is located in central Taiwan and has a combination of commercial, industrial and agricultural economic activities (4). Chiayi (23.3°N) and Tainan (23.1°N), which are the two largest farming areas in Taiwan, are located to the south of the Tropic of Cancer and have a population of about 2.7 million in total. Their main economic activities include the production of rice, fruits and vegetables from cultivated fields and fishery products from inland fish farms, accounting for 18–25% of agriculture production and 24% of fishery production, as measured in metric tonnes, in Taiwan (4, 5).

Over the past 30 years, meteorological data from the three largest metropolitan areas in Taiwan (i.e. Taipei, Taichung and Kaohsiung) have shown hot seasons with an average maximum temperature above 30°C, lasting four to five months, with a mean relative humidity ranging from 74 to 82% (Fig. 1A–C) (6). Meteorological data from the two largest farming areas (i.e. Chiayi and Tainan) also show similar high temperatures in hot seasons, with an average maximum temperature above 30°C, lasting five to six months, and even higher humidity, ranging from 77 to 85% (Fig. 1D and E) (6).

Typically, the temperature of Taiwan varies during the four seasons and peaks in July. On average, monthly mean temperatures range from 15.8 to 29.2°C in metropolitan areas and from 16.1 to 29.0°C in farming areas (6). However, a recent nationwide report indicated that the average temperatures measured at five Taiwan weather stations in July have shown an increase in temperature by 1.6°C over the past century (7).

Occupations and industries at risk of heat stress in Taiwan

Labourers who work in hot indoor or outdoor environments in Taiwan include construction workers (roads and roofs), farming and fishing workers, cooks (in bakeries and kitchens), metal and glass manufacturers (for instance, in steel and bicycle factories), and transportation workers and material movers (for example, postal deliverers and traffic policemen). Of these, construction (SIC Division C) workers accounted for the largest portion of the labour force that works outdoors, with around 842,000 workers (8.1% of the labour force), whereas agriculture, forestry and fishing (SIC Division A) workers accounted for 535,000 workers (5.1%) in 2008 (Table 1) (8). A total of 11,000 agriculture, forestry, fishing and construction workers are foreign labourers from Thailand, Indonesia, the Philippines and Vietnam (9). Foreign workers are recruited to Taiwan mainly because of cheaper labour costs, but also on account of the notion that they have greater heat stress endurance than local workers. Anecdotal stories of sudden deaths, possibly due to excess heat during work, have been occasionally reported in the past. Workers in construction, farming and fishery industries may also suffer from high occupational temperature impacts on health and productivity due to climate change, as suggested by Kjellstrom (10). These workers are a potentially high-risk population in Taiwan because they have to work under hot and humid summer conditions, which last for more than five months. More than a million workers are employed in these industries, and they contributed around 3.4% of the real GDP of Taiwan in 2008 (11). The effect of heat on these workers' health and work output is an important public health issue in Taiwan.

Surveys of employees' perceptions of safety and health in the work environment have been routinely conducted via questionnaires every three years since 1988, primarily by the Taiwan Institute of Occupational Safety and Health. The most recent survey of 19,000 workers indicated that 42% of employees perceived a risk of excessive heat at the workplace (12). The proportion of employees who perceived risk was particularly high in the construction industry (76.3%) and in the agriculture, forestry and fishing industries (71.3%) (12). Compared to data from 2001, these rates were higher in both sets of industries in 2007 (Fig. 2), whereas the rate for the total workforce decreased slightly (12–14). A decrease in perceived risk of excessive heat amongst the total workforce may be due to the increased use of air conditioning in indoor workplaces. Note that the proportion of employees who perceived a risk of excessive heat at the workplace is higher in males (50.97%) and in those with lower educational levels (63.51–78.15% for junior high level or below) (12).

However, information regarding actual exposure to hot work environments for these workers remains unclear, especially for outdoor construction sites and farming operations during hot summer months, raising concern about the effect of heat stress on workers' health and productivity. Two studies have attempted to investigate heat exposure levels and workers' symptoms of fatigue in hot workplaces in Taiwan (15, 16). One investigation on workers' heat exposure at hot workplaces during summer months (i.e. from July to September) showed that averages of the wet bulb globe temperature (WBGT) index at 54 workplaces ranged from 21.4 to 40.1°C, and 51.4% of the measured WBGT values exceeded the recommended WBGT level for the 212 workers in these workplaces (15). The unusually high WBGT levels measured in this survey were caused by a combination of heat generated indoors and natural heat outdoors (15). Another study showed that subjective symptoms of shoulder pain, lower back pain and thirst in 151 workers

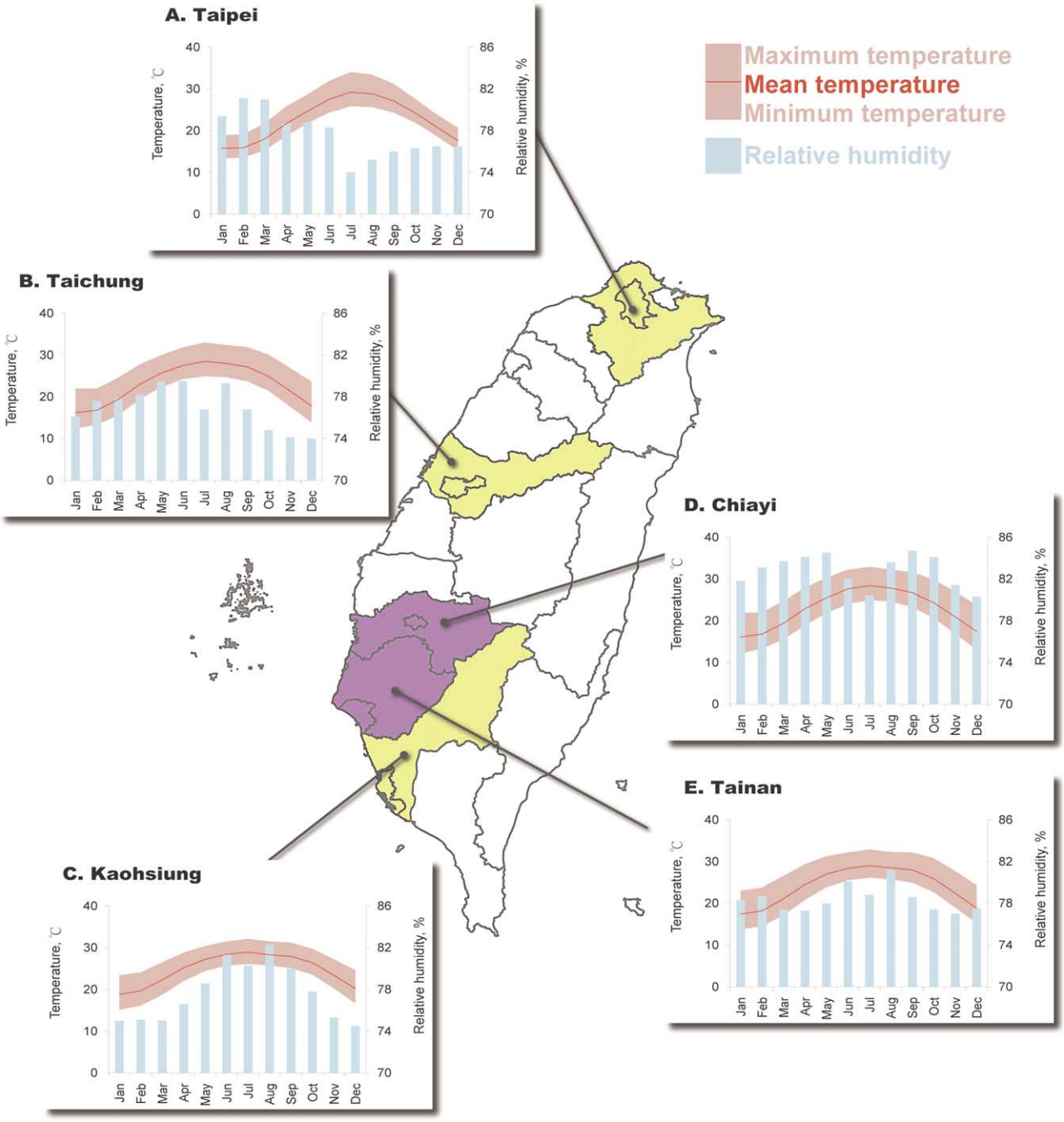

Fig. 1. Meteorological data showing monthly averages for daily mean, minimum, and maximum temperature and monthly averages for relative humidity in three metropolitan areas (A–C) and two farming areas (D and E) over the past 30 years (Source 6).

in steel, glass and porcelain manufacturing plants were related to high WBGT indexes (range: 19.6–34.6°C) at their worksites (16).

Regulations and prevention of excessive heat exposure in workplaces and households

The Labour Safety and Health Act in Taiwan prevents workers from being exposed to unusually high temperatures for more than six hours per day (17). According to the WBGT-based Work-Rest Regime Standards for Workers in Hot Workplaces in Taiwan, permissible heat exposure in hot environments is based on the type of work being performed; for example, the WBGT of an area of continuous work should not exceed 30.6°C for light workloads, 28.0°C for moderate workloads, or 25.9°C for heavy workloads (18). Employers

Table 1. Description of all working populations and workers in industries at risk of excessive heat in Taiwan, in 2008 (Sources 8, 11)

Industries, by sex	Employed persons (in thousands)	Work hours per week	Educational level equal to junior high school or below (%)	Real GDP, new Taiwan dollars (in millions)
Both sexes				
All industries	10,403	43.83	25	13,089,718
Construction	842	40.41	48	173,060
Agriculture, forestry and fishing	535	40.24	74	271,594
Males				
All industries	5,902	44.19	27	–
Construction	746	40.37	50	–
Agriculture, forestry and fishing	374	40.40	71	–
Females				
All industries	4,501	43.35	21	–
Construction	96	40.74	33	–
Agriculture, forestry and fishing	162	39.88	80	–

are required to ensure that employees who work in certain environments be provided with personal equipment that protects them from heat exposure, as well as drinking water and salt (18). These places include boiler and furnace rooms, places in which steel and non-ferrous metals are smelted or cast, ceramic, glass and carbide furnace plants and steam tunnels (18). According to the Workplace Environmental Monitoring Regulation, workplaces should be inspected at least once every three months when the WBGT of the workplace exceeds the limit of the criteria (19).

However, such regulation is difficult to enforce in farming, fishing and construction industries, where the WBGT of outdoor workplaces is not directly measured and can only be indirectly inferred from local meteorological monitoring data. About 83% of farming and fishery workers are self-employed or household labourers (8) and are not equipped to measure the WBGT themselves. Around 84% of construction workers are employees (8), and they have to work during hot days to fulfil the required tasks for a set period of time.

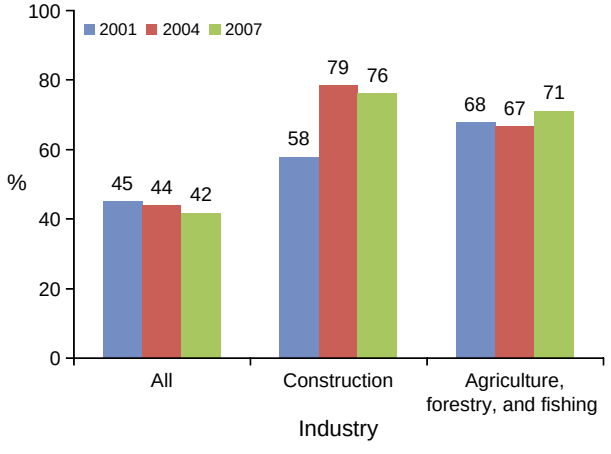

Fig. 2. Percentage of employees who perceived a risk of excessive heat at the workplace: all industries; construction industries and agriculture, forestry and fishing industries in 2001, 2004 and 2007 (Sources 12–14).

On average, construction workers worked 40.41 hours per week in 2008 (8). In Taiwan, workers take one hour off for lunch, usually from 12:00 to 13:00, at shady places to avoid direct sun exposure. In addition to following the criteria of work and rest, these workers are usually shirtless and wear helmets, quenching their thirst with either alcohol, energy drinks or herbal teas.

Construction workers usually live in dormitories near construction sites. The dormitories are usually tin-plate huts and are sometimes not furnished with air conditioners. Workers often feel uncomfortable living in such conditions, especially during the hot and humid summer (20). The common way to reduce heat stress at these dormitories is to open windows to increase natural ventilation or to use fans when air conditioners are not available.

The working period for farmers depends on the season of harvest. The first crop of rice, for example, is harvested during the hot season from May to August, followed by the second crop, harvested from September to January (21). The average working hours in agriculture, forestry and fishing industries were 40.24 hours per week in 2008 (8). Farmers may work shirtless and wear wide-brimmed hats to avoid overheating at work. However, some farmers wear protective clothes and masks to reduce pesticide exposure (22), which may increase the risk of heat-related illness. Most farmers live in their own houses and use fans

or air conditioners to reduce heat exposure. Commuting from their houses to the farms may also increase heat exposure, because farmers travel to their workplace on foot or by bicycle or motorcycle.

Conclusions

Epidemiological studies and reports in Taiwan have highlighted the impact of warmer climate on several infectious diseases, such as dengue fever and enteroviral infection (23–25). However, the impact of a warmer climate on workers' health and productivity has not been analysed. Farmers' heat-related deaths exemplify the vulnerability of older farmers and fishermen working in hot climates. The fact that agricultural workers tend to be older raises the question of whether they have appropriate protection in overheated environments (Fig. 3) (8). Moreover, tight protective clothing protecting against pesticide exposure may increase the risk of heat stress among farm workers. Heavy physical workloads can also pose a threat of heat fatigue among construction workers, which is likely to increase the risk of accidents and injuries at construction worksites.

This report has outlined the risks that heat poses for workers' health. Construction and farming workers, especially elderly workers, are the most vulnerable occupational groups that may be exposed to heat at worksites for long durations. Their health and work capacity are among the major concerns for the nation's economic development.

As a result of global warming, we should assess the impact of local climate change on workers' health and productivity in Taiwan, both qualitatively and quantitatively. New studies can provide labour and health policymakers, as well as safety and health practitioners, with essential information about the effects of heat on health and productivity. Such studies can address prevention strategies that would provide these workers with a better working and living environment.

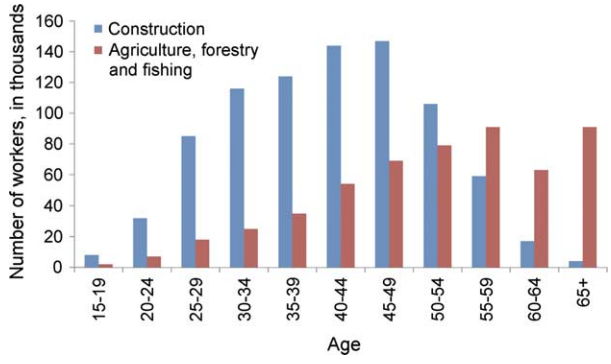

Fig. 3. Age distribution of employed persons by industry in 2008 (Sources 8).

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Conflict of interest and funding

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